pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

BUREAU OF CLEAN WATER
UNT SUSQUEHANNA RIVER (BRUSH VALLEY CREEK) SEDIMENT TMDL
NORTHUMBERLAND COUNTY
May 26, 2023; DRAFT FOR PUBLIC COMMENT

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2023

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

"Total Maximum Daily Loads" (TMDLs) for sediment were developed for an Unnamed Tributary to (UNT) the Susquehanna River watershed (Figure 1) to address the siltation impairments noted in the 2022 Final Pennsylvania Integrated Water Quality Monitoring and Assessment Report (Integrated Report), including the Clean Water Act Section 303(d) List. Agriculture was identified as the source of these impairments. Because Pennsylvania does not have numeric water quality criteria for sediment, the loading rates from a similar unimpaired watershed were used to calculate the TMDLs.

"TMDLs" were calculated using both a long-term annual average value ($TMDL_{Avg}$) which would be protective under most conditions, as well as a 99th percentile daily value ($TMDL_{Max}$) which would be relevant to extreme flow events. Current annual average sediment loading in the UNT Susquehanna River watershed was estimated to be 1,586,060 pounds per year. To meet water quality objectives, annual average sediment loading should be reduced by 9% to 1,446,929 pounds per year. Allocation of annual average sediment loading among the TMDL variables is summarized in Table 1. To achieve this reduction while maintaining a 10% margin of safety and minor allowance for point sources, annual average loading from croplands, hay/pasture lands and streambanks should each be reduced by 19%.

Table 1. Summary of annual average TMDL ($TMDL_{Avg}$) variables for the UNT Susquehanna River watershed. All values are in lbs/yr.

Pollutant	$TMDL_{Avg}$	MOS_{Avg}	WLA_{Avg}	LA_{Avg}	LNR_{Avg}	ALA_{Avg}
Sediment	1,446,929	144,693	14,469	1,287,767	6,486	1,281,280

TMDL=Total Maximum Daily Load; MOS = Margin of Safety; WLA=Wasteload Allocation (point sources); LA = Load Allocation (nonpoint sources). The LA is further divided into LNR = Loads Not Reduced and ALA=Adjusted Load Allocation. Subscript "Avg" indicates that these values are expressed as annual averages.

Current 99th percentile daily loading in the UNT Susquehanna River watershed was estimated to be 69,214 pounds per day. To meet water quality objectives, 99th percentile daily sediment loading should be reduced by 12% to 60,818 pounds per day. Allocation of 99th percentile daily sediment loading among the TMDL variables is summarized in Table 2.

Table 2. Summary of 99th percentile daily loading TMDL ($TMDL_{Max}$) variables for the UNT Susquehanna River watershed. All values are in lbs/d.

Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}	LNR_{Max}	ALA_{Max}
Sediment	60,818	6,082	608	54,128	273	53,856

TMDL=Total Maximum Daily Load; MOS = Margin of Safety; WLA=Wasteload Allocation (point sources); LA = Load Allocation (nonpoint sources). The LA is further divided into LNR = Loads Not Reduced and ALA=Adjusted Load Allocation. Subscript "Max" indicates that these values are expressed as 99th percentile for daily loading.

INTRODUCTION

In accordance with the Pennsylvania Department of Environmental Protection’s (DEP) 2022 Integrated Report GIS viewer, the study watershed (Figure 1) will be referred to as the UNT Susquehanna River watershed. However, the stream is locally known as “Brush Valley Creek”. The stream’s confluence with the Susquehanna River is less than a mile southwest of the City of Sunbury (Figures 1 and 2), and the entire 2.8 square mile watershed occurs within Northumberland County. The watershed contains approximately 5.6 stream miles, all of which are currently designated Warm Water Fishes, Migratory Fishes at 25 Pa. Code § 93.

This Total Maximum Daily Load (TMDL) document has been prepared to address the siltation from agriculture impairments listed for most of the watershed, per the Integrated Report (Figure 1, Table 3; see also Appendix A for a description of assessment methodology). Since the outlet of the watershed is listed as impaired for sediment, this TMDL document will be relevant to all segments within the watershed, including those that were not listed as impaired.

The removal of natural vegetation and soil disturbance associated with agriculture increases soil erosion leading to sediment deposition in streams. Excessive fine sediment deposition may destroy the coarse-substrate habitats required by many stream organisms. While Pennsylvania does not have numeric water quality criteria for sediment, it does have applicable narrative criteria:

> *Water may not contain substances attributable to point or nonpoint source discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life. (25 Pa. Code § 93.6 (a))*
>
> *In addition to other substances listed within or addressed by this chapter, specific substances to be controlled include, but are not limited to, floating materials, oil, grease, scum and substances which produce color, tastes, odors, turbidity or settle to form deposits. (25 Pa. Code, § 93.6 (b))*.

While agriculture has been identified as the source of the impairments (Table 3), this TMDL document is applicable to all significant sources of solids that may settle to form deposits.

According to an analysis of National Land Cover Database (NLCD) 2019 land cover data, as reported by Model My Watershed, the study watershed was estimated to be 52% agriculture, 39% forest/naturally vegetated lands, and 10% mixed development. Of the agricultural lands, there were nearly three times the amount of croplands as hay/pasture lands (Appendix B, Table B1). Given that agriculture was the primarily land cover in the watershed, and that croplands, which tend to have the highest sediment loading rates of land covers common to Pennsylvania were especially abundant, the presence of siltation impairments would be expected. There were no current National Pollutant Discharge Elimination System (NPDES) permitted point source discharges in the watershed with significant load limits relevant to sedimentation (Table 4).

Table 3. Aquatic Life Use impaired stream segments in the UNT Susquehanna River watershed per the 2022 Final Pennsylvania Integrated report (DEP 2022b). See Appendix A for more information on the listing process.

Source	USEPA 305(b) Cause Code	Miles
Agriculture	Siltation	3.7
Agriculture	Organic Enrichment	3.7

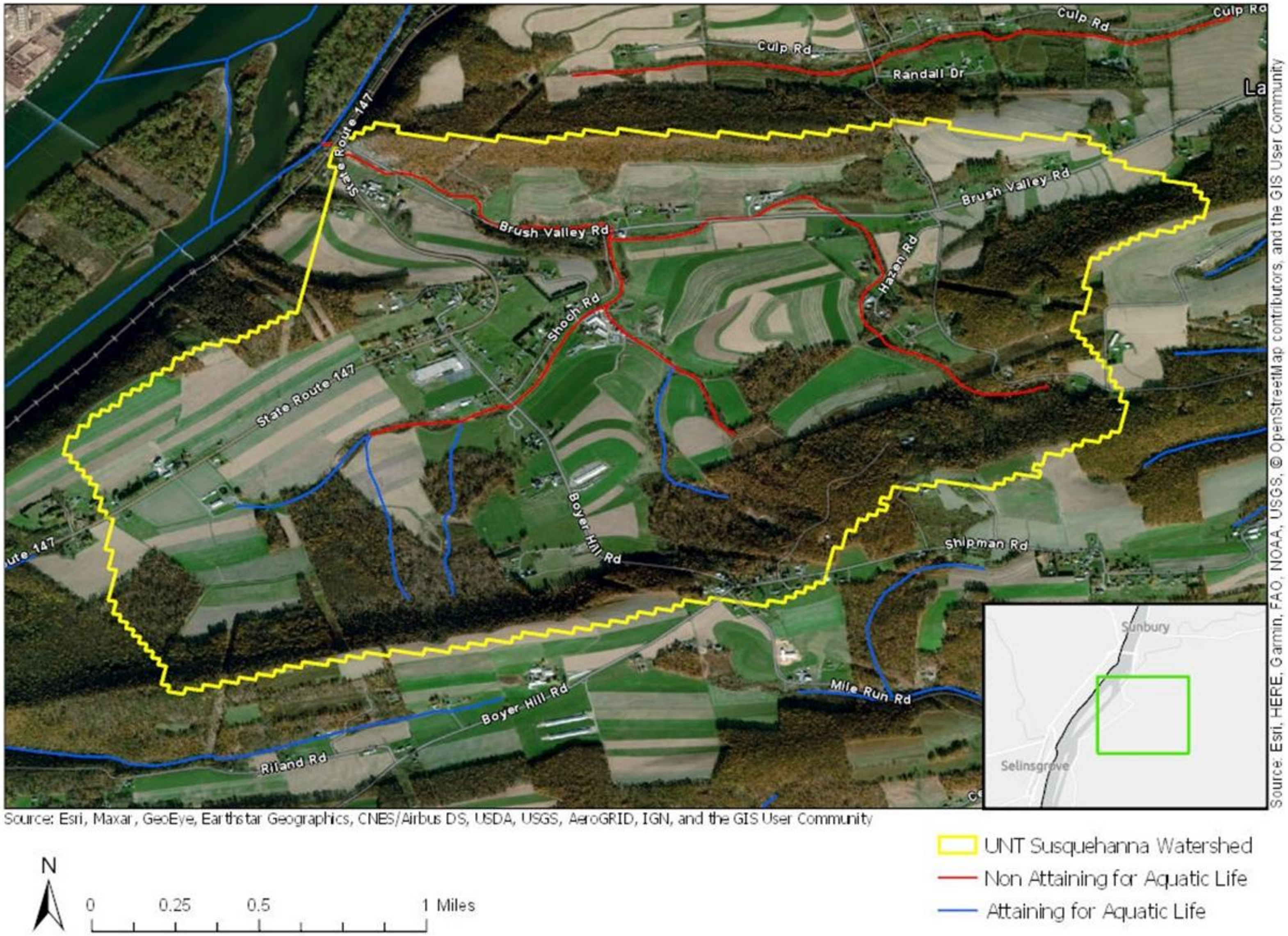

Figure 1. UNT Susquehanna River watershed. Per the 2022 Integrated Report viewer, the Aquatic Life Use impairments within the watershed were due to siltation and organic enrichment from agriculture (DEP 2022b).

Table 4. Existing NPDES-permitted discharges in the UNT Susquehanna River watershed and their potential contribution to sediment loading. Given their transient nature, stormwater construction permits were not included.

Permit No.	Facility Name	Permit Based Limits		DMR Based Loading	
		Load, mean (lbs/yr)	**Load, max** (lbs/d)	**Load, mean** (lbs/yr)	**Load, max** (lbs/d)
None	NA	NA	NA	NA	NA

Permits within the delineated watershed were based on eMapPA (DEP 2022a) and Watershed Resources Registry (USEPA 2022).

TMDL APPROACH

Although watersheds must be handled on a case-by-case basis when developing TMDLs, there are basic processes that apply to all cases. They include:

1. Collection and summarization of pre-existing data (watershed characterization, inventory contaminant sources, determination of pollutant loads, etc.);
2. Calculation of a TMDL that appropriately accounts for critical conditions and seasonal variations;
3. Allocation of pollutant loads to various sources;
4. Submission of draft reports for public review and comments; and
5. United States Environmental Protection Agency (USEPA) approval of the TMDL.

Because Pennsylvania does not have numeric water quality criteria for sediment, the “Reference Watershed Approach” was used. This method estimates pollutant loading rates in both the impaired watershed as well as a similar watershed that is not listed as impaired for the same use. Then, the loading rate in the unimpaired watershed is scaled to the area of the impaired watershed so that necessary load reductions may be calculated. It is assumed that reducing loading rates in the impaired watershed to the levels found in the reference watershed will result in the amelioration of the siltation impairments.

SELECTION OF THE REFERENCE WATERSHED

In addition to anthropogenic influences, there are many other natural factors affecting sediment loading and accumulation rates in a watershed. Thus, selection of a reference watershed with similar natural characteristics as the impaired watershed is crucial. Failure to use an appropriate reference watershed could result in problems such as the setting of sediment reduction goals that are unattainable, or nonsensical TMDL calculations that suggest that sediment loading in the impaired watershed should be increased.

To find a reference, GIS data layers largely consistent with the 2020 Integrated Report (DEP 2020) were used to search for nearby watersheds that were of similar size as the UNT Susquehanna River watershed, but lacked stream segments listed as impaired for sediment. Once potential references were identified, they were screened to determine which ones were most like the impaired watershed with regard to factors such as landscape position, topography, hydrology, soil drainage types, land covers etc. Furthermore, benthic macroinvertebrate and physical habitat assessment scores were reviewed to confirm that a reference was acceptable. Preliminary modelling was conducted to make sure that use of a particular reference would result in a reasonable pollution reduction.

Considering that: it was nearby (only about seven miles to the northwest), within the same physiographic province, had similar topography and hydrologic characteristics, and there was good evidence that it was supporting its Aquatic Life Use, a subwatershed of an unnamed tributary of Penns Creek (henceforth “UNT Penns Creek subwatershed”) in Snyder County was considered for use as a reference (Figures 2 and 3, Table 5).

Table 5. Comparison of the UNT Susquehanna River and UNT Penns Creek watersheds.

	UNT Susquehanna	**UNT Penns**
Phys. Province[1]	Susquehanna Lowland Section of the Ridge and Valley Physiographic Province	Susquehanna Lowland Section of the Ridge and Valley Physiographic Province
Land Area[2], ac	1,824	1,836
Land Cover[2]	52% Agriculture 39% Forest/Natural Vegetation 10% Developed	52% Agriculture 41% Forest/Natural Vegetation 8% Developed
Soil Infiltration[3]	36% Group A 14% Group B 1% Group B/D 11% Group C 1% Group C/D 37% Group D	51% Group A 16% Group B 1% Group B/D 6% Group C 1% Group C/D 26% Group D
Dominant Bedrock[4]	77% Shale 23% Calcareous Shale	76% Mudstone 24% Siltstone
Average Precipitation[5], in/yr	41.5	41.5
Average Surface Runoff[5], in/yr	2.8	2.6
Average Elevation[5], ft	660	720
Average Slope[5]	14%	13%

Average Stream Channel Slope (High Resolution NHD)[5]	1st order: 4.62% 2nd order: 1.75% 3rd order: 1.24	1st order: 4.09% 2nd order: 1.32%

[1]Per pags_physsections2008 GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources
[2]MMW output based on NLCD 2019
[3]As reported by Model My Watershed's analysis of USDA gSSURGO 2016. A = high infiltration soils; B=moderate infiltration soils, C= slow infiltration soils and D= very slow infiltration soils. See technical documentation for more details.
[4]Per bedrock geology (V) GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Department of Conservation and Natural Resources
[5]As reported by Model My Watershed

Both watersheds were within the Susquehanna Lowland section of the Ridge and Valley Physiographic Province (Table 5). Approximately half the land area of both watersheds was agriculture, with the bulk of the remaining land area as forested/natural vegetation landcover (Table 5 and Appendix Tables B1 and B2). Furthermore, approximately a tenth the land area in both watersheds were developed lands.

Both watersheds were dominated by non-karst sedimentary bedrocks, though shale was by far the dominant bedrock in the UNT Susquehanna River watershed whereas the UNT Penns Creek subwatershed was dominated by mudstone (Table 5). The average topographic slope as well as average stream channel slopes in both watersheds were similarly high (Table 5). Both watersheds had a wide range of soil drainage types, and estimated surface runoff rates were nearly the same (Table 5).

Whereas stream segments within the UNT Susquehanna River watershed are currently designated Warm Water Fishes, Migratory Fishes, stream segments within the UNT Penns Creek subwatershed are currently designated for Cold Water Fishes, Migratory Fishes at 25 Pa. Code § 93. Neither watershed had stream segments with special protection designations (High Quality or Exceptional Value). Also, like the UNT Susquehanna River watershed, there were no significant NPDES permitted point source discharges in the UNT Penns Creek subwatershed (Table 6). Overall, the two watersheds appeared to be very similar.

Table 6. Existing NPDES-permitted discharges in the UNT Penns Creek subwatershed and their potential contribution to sediment loading. Given their transient nature, stormwater construction permits were not included.

Permit No.	**Facility Name**	**Permit Based Limits**		**DMR Based Loading**	
		Load, mean (lbs/yr)	**Load, max** (lbs/d)	**Load, mean** (lbs/yr)	**Load, max** (lbs/d)
None	NA	NA	NA	NA	NA

Permits within the delineated watershed were based on eMapPA (DEP 2022a) and Watershed Resources Registry (USEPA 2022).

After selecting the potential reference, the two watersheds were visited during March 2021 to confirm the suitability of the reference as well as to explore whether there were any obvious landcover differences that may help explain why one watershed was impaired for sediment while the other was not.

Site observations in the UNT Susquehanna River watershed indicated highly variable streambed substrate conditions (Figures 4 and 5). For instance, a high gradient reach near the mouth was primarily rocky, with little fine sediment deposition (Figure 4). However, an apparently lower gradient reach a short ways upstream exhibited obvious fine sediment deposition (Figure 4). Sites within the middle and upper watershed were also variable, ranging from minor to severe fine sediment deposition (Figure 5).

It is hypothesized that topographic conditions may help explain the sporadic patterns of fine sediment deposition in the watershed. Sediment loading to the watershed was expected to be high given the amount and intensity of agriculture in the watershed (Figures 1 and 6, Table 5). Yet, stream slopes were also quite high on average (Table 5), and high gradient reaches may be able to export large quantities of sediment without exhibiting high rates of fines deposition. This may explain why fine sediments appeared to be accumulating in more sluggish reaches that may be especially vulnerable to deposition (Figures 4 and 5).

In addition to the amount and intensity agriculture in the watershed, there were also obvious examples where practices and conditions could have been improved. For instance, croplands were sometimes observed on steep slopes that drained towards stream segments that lacked expansive riparian buffers (Figure 7). In some cases cattle had direct access to streams and drainageways, and this may have been contributing to severe bank erosion (Figure 7). It should also be noted that conditions that may be protective against sediment loading were also observed, including the use of: riparian buffers, cattle exclusion fencing, contour farming, high levels of crop residue, cover crops, and bank stabilization structures (Figures 7 and 8).

Streambed conditions appeared to be better on average in the UNT Penns Creek subwatershed versus the UNT Susquehanna River watershed (Figures 9 and 10). Streambeds tended to be rocky throughout the watershed, though with some localized exceptions, especially in pools/slow reaches (Figures 9 and 10). However, widespread severe impairments comparable to those shown in Figures 4 and 5 were not observed.

As was the case for the UNT Susquehanna River watershed, there was also a high amount of agriculture in the UNT Penns Creek subwatershed. However, while agricultural lands were often in close proximity to streams in the UNT Susquehanna River watershed (Figures 1 and 7), agricultural areas tended to be concentrated within the uplands of the UNT Penns Creek subwatershed (Figures 3 and 11). Large forested tracts, which may be protective of water quality, often occurred along stream segments in the UNT Penns Creek subwatershed (Figures 3, 11 and 12). Even so, there were also examples of conditions that could have clearly been improved in the UNT Penns Creek subwatershed, such as: areas where agricultural lands drained to unbuffered stream segments, and an especially notable case where cattle grazing on steep lands resulted in obvious erosion (Figure 13). Despite this, all stream segments within the watershed were listed as supporting their Aquatic Life Use per the approved Integrated Report.

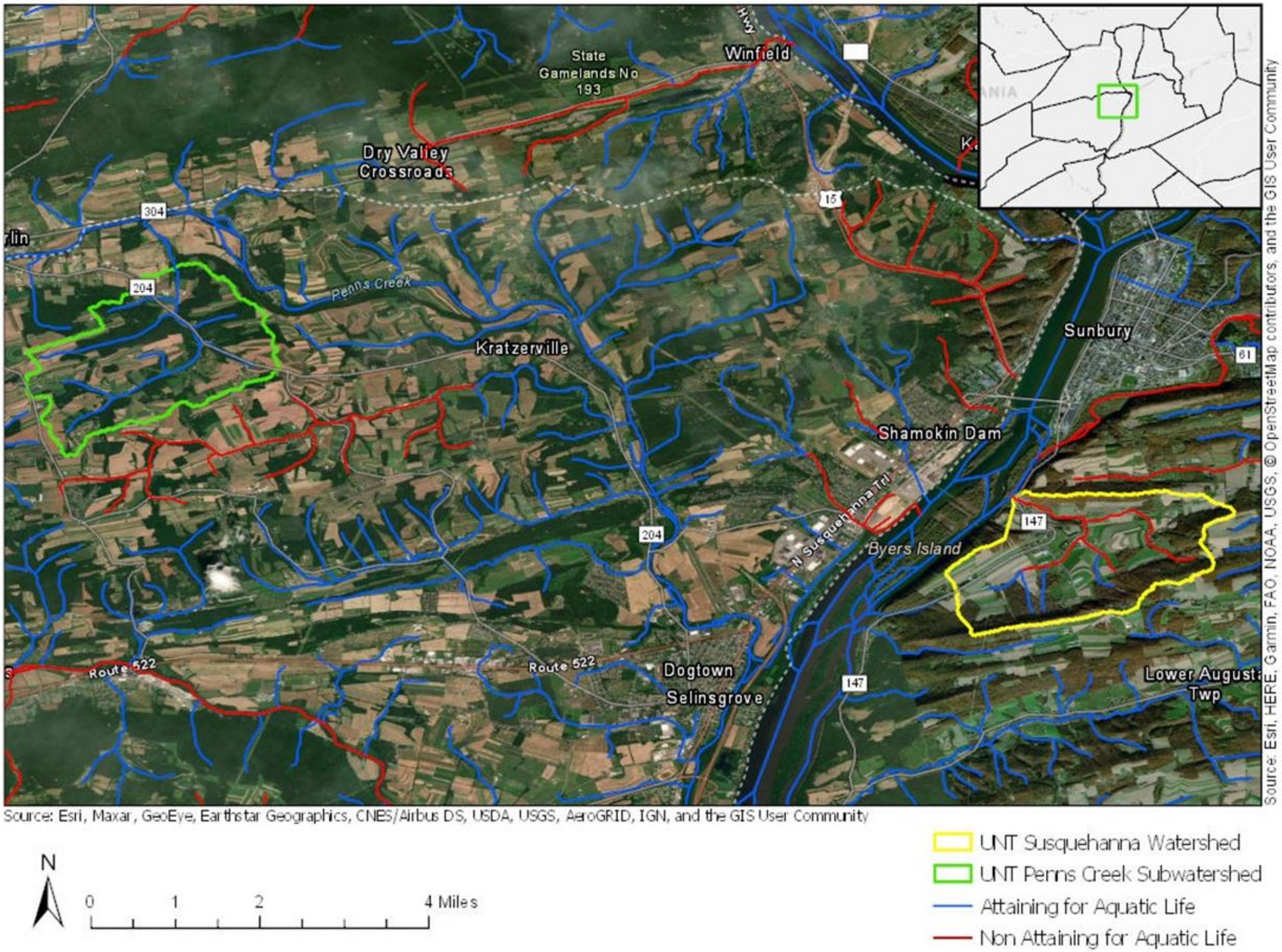

Figure 2. UNT Susquehanna River and UNT Penns Creek watersheds. Stream segments within these two watersheds are shown as either supporting or Aquatic Life Use impaired per the 2022 Integrated Report viewer (DEP 2022b).

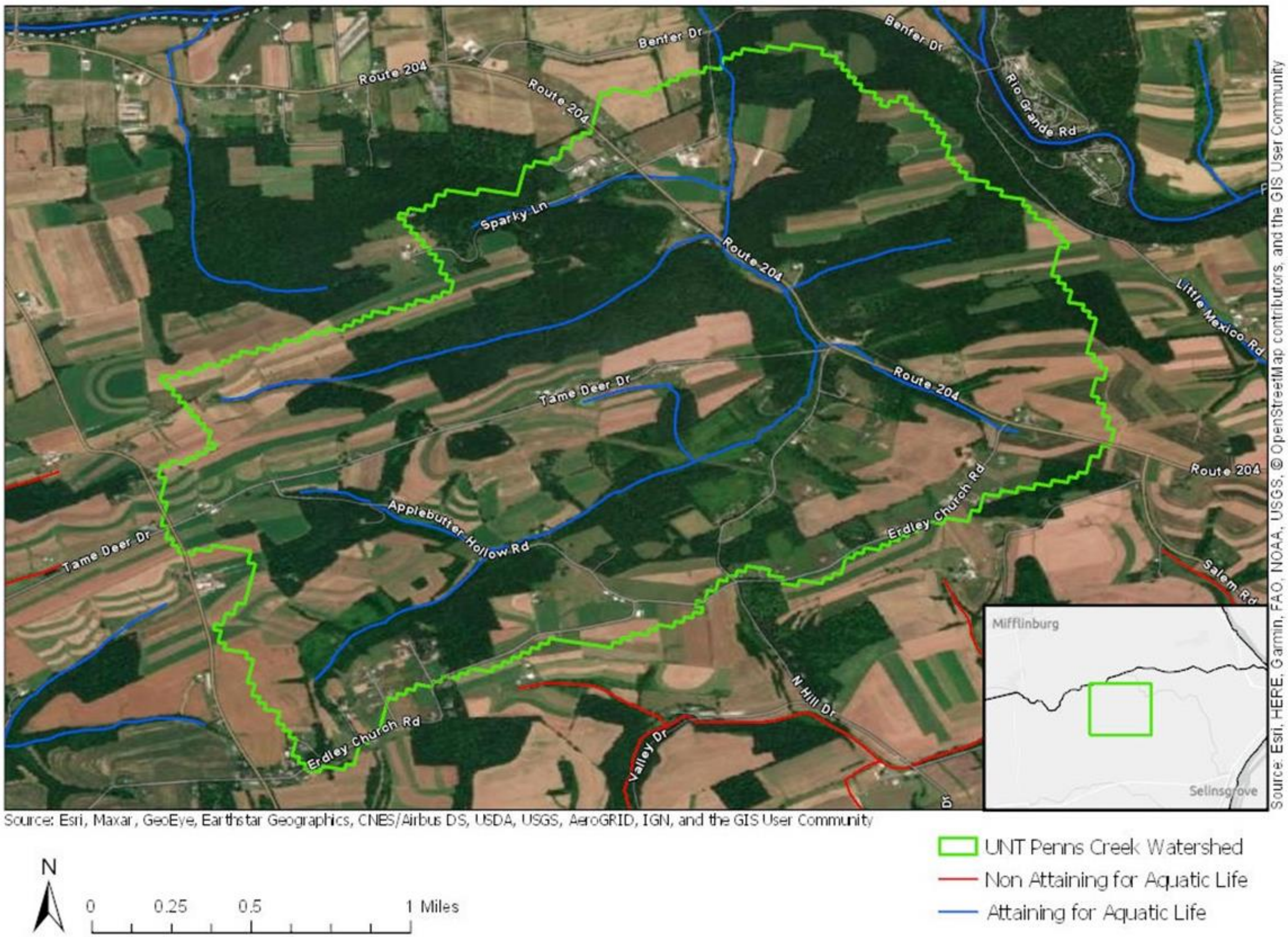

Figure 3. UNT Penns Creek subwatershed. All stream segments within the watershed were listed as supporting their Aquatic Life Use per the Integrated Report viewer (DEP 2022b).

Figure 4. Substrate conditions within the lower mainstem of the UNT Susquehanna River watershed. Higher gradient areas were comprised primarily of rocky substrate with little fines deposition (A and B). In contrast, fines deposition was apparent in lower gradient reaches just upstream (C and D).

Figure 5. Substrate conditions in the middle and upper reaches of the UNT Susquehanna River watershed. Larger reaches of the upper watershed often exhibited moderate (A) to severe (B) fines deposition. In contrast, very small tributaries (C and D) tended to be primarily rocky, as they were often high gradient and originated in forested areas.

Figure 6. Landscapes within the UNT Susquehanna River watershed. The steep upland margins of the watershed were often forested while most of the rest of the watershed consisted of hilly agricultural lands.

Figure 7. Agricultural conditions that may exacerbate sediment loading in the UNT Susquehanna River watershed. Photograph A shows an example of sloping croplands draining towards a stream without an expansive forested buffer. However, it appears that at least some herbaceous buffer was present. Also note the formation of gully erosion. Photograph B shows sloping croplands draining towards a stream running through a pasture. Note the excessive bank erosion. While cattle had been fenced out of the mainstem shown in the background of C, they still had access to the small tributary/drainageway that ran through the pasture. Photograph D shows a stream segment running through a pasture where cattle had direct access to the stream. Note the severe bank erosion and sediment deposition.

Figure 8. Factors that may be protective against sediment loading in the UNT Susquehanna River watershed. Photographs A and B show stream segments with forested riparian buffers. Photograph C shows an apparent stream restoration project with cattle exclusion fencing, the growth of an herbaceous buffer, and structures that may help prevent bank erosion. Photograph D shows an area with new riparian buffer plantings.

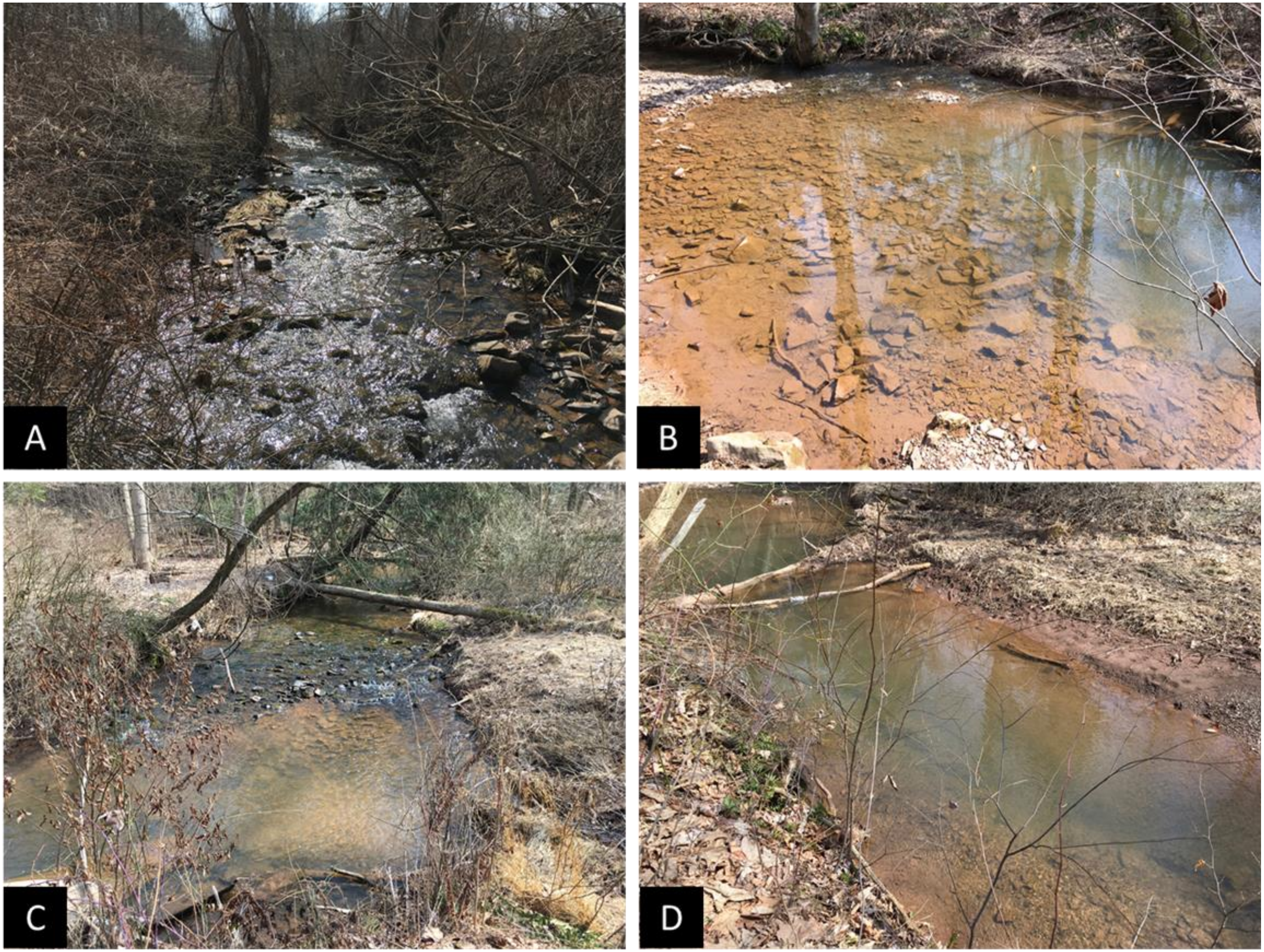

Figure 9. Substrate conditions within the downstream area of the UNT Penns Creek subwatershed. Conditions were primarily rocky in higher gradient areas (A) and some pools (B), though substantial fines deposition could also be observed in some pools (C and D).

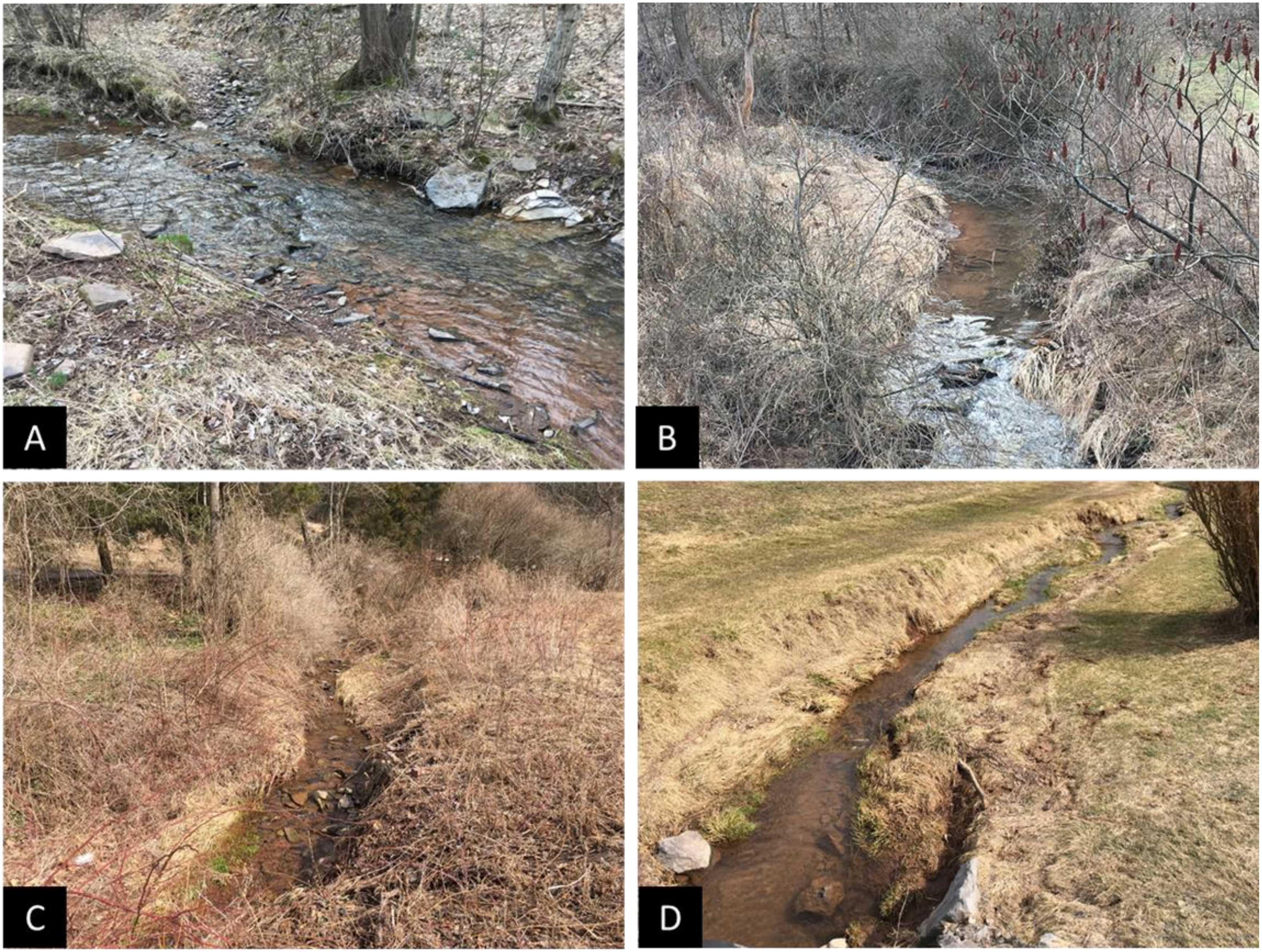

Figure 10. Substrate conditions within the middle and upper reaches of the UNT Penns Creek subwatershed. Streambeds in these areas were primarily rocky, though sometimes with moderate fines deposition as in B and D.

Figure 11. Landscapes within the UNT Penns Creek subwatershed. The uplands were dominated by agricultural areas whereas forests tended to occur in the valleys along stream segments.

Figure 12. Factors protecting water quality in the UNT Penns Creek subwatershed. Many stream segments passed through forested areas (A and B) or had forested riparian buffers (C). Photograph D shows the use of contour farming, cover crops and high levels of crop residue in an upland agricultural area.

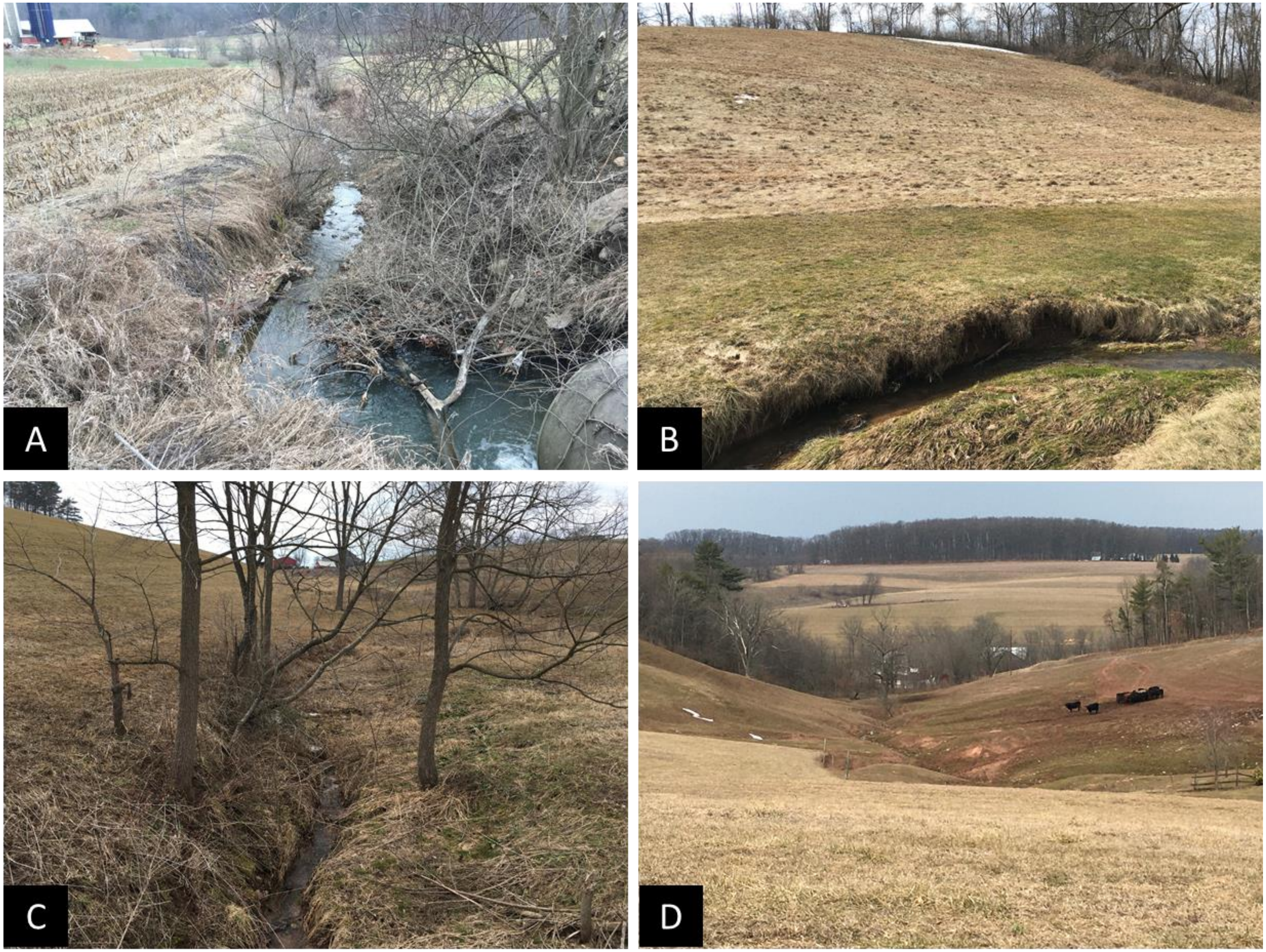

Figure 13. Examples of conditions that may exacerbate sediment loading in the UNT Penns Creek subwatershed. Some stream segments/drainageways lacked expansive riparian buffers (A-D). Figure D shows a steep drainageway with degraded pasture lands and obvious bank erosion.

HYDROLOGIC / WATER QUALITY MODELING

This section deals primarily with the $TMDL_{Avg}$ calculation, as use of annual average values was determined to be the most relevant way to express the "TMDL" variables. For information about the $TMDL_{Max}$ calculations, see the later "Calculation of a Daily Maximum '$TMDL_{Max}$'" section.

Estimates of sediment loading for the impaired and reference watersheds were calculated using the "Model My Watershed" application (MMW-Version 1.34.1, though watershed delineations were made with a prior version), which is part of the WikiWatershed web toolkit developed through an initiative of the Stroud Water Research Center (Stroud Water Research Center 2023). MMW is a replacement for the MapShed desktop modelling application. Both programs calculate sediment and nutrient fluxes using the "Generalized Watershed Loading Function Enhanced" (GWLF-E) model. However, MapShed was built using a MapWindow GIS package that is no longer supported, whereas MMW operates with GeoTrellis, an open-source geographic data processing engine and framework. The MMW application is freely available for use at https://wikiwatershed.org/model/. In addition to the changes to the GIS framework, the MMW application continues to be updated and improved relative to its predecessor.

In the present study, watershed areas were defined using MMW's Watershed Delineation tool (https://wikiwatershed.org/documentation/mmw-tech/#delineate-watershed). Then, the mathematical model used in MMW, GWLF-E, was used to simulate 30-years of daily water, nitrogen, phosphorus and sediment fluxes. To provide a general understanding of how the model functions, the following excerpts are quoted from MMW's technical documentation.

> *The GWLF model provides the ability to simulate runoff, sediment, and nutrient (nitrogen and phosphorus) loads from a watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. It is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads based on the daily water balance accumulated to monthly values.*
>
> *GWLF is considered to be a combined distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple landuse/cover scenarios, but each area is assumed to be homogenous in regard to various "landscape" attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but simply aggregates the loads from each source area into a watershed total; in other words there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for sub-surface flow contributions. Daily water balances are computed for an unsaturated zone as well as a saturated subsurface zone, where infiltration is simply computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.*

With respect to major processes, GWLF simulates surface runoff using the SCS-CN approach with daily weather (temperature and precipitation) inputs from the EPA Center for Exposure Assessment Modeling (CEAM) meteorological data distribution. Erosion and sediment yield are estimated using monthly erosion calculations based on the USLE algorithm (with monthly rainfall-runoff coefficients) and a monthly KLSCP values for each source area (i.e., land cover/soil type combination). A sediment delivery ratio based on watershed size and transport capacity, which is based on average daily runoff, is then applied to the calculated erosion to determine sediment yield for each source sector. Surface nutrient losses are determined by applying dissolved N and P coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area.

Evapotranspiration is determined using daily weather data and a cover factor dependent upon landuse/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values.

Streambank erosion is calculated as a function of factors such as the length of streams, the monthly stream flow, the percent developed land in the watershed, animal density in the watershed, the watersheds curve number and soil k factor, and mean topographic slope. For a detailed discussion of this modelling program, including a description of the data input sources, see Evans and Corradini (2016) and Stroud Research Center (2023).

MMW allows the user to adjust model parameters, such as the area of land coverage types, the use of conservation practices and the efficiencies of those conservation practices, the watershed's sediment delivery ratio, etc. Default values were used for the modelling run. Following the model run, a correction for the presence of existing riparian buffers was made in a BMP Spreadsheet Tool (Evans et al. 2020) that had been provided by MMW. The following paragraphs describe the riparian buffer correction method.

Riparian buffer coverage was estimated via a GIS analysis in ArcGIS Pro (Figures 14 and 15). Briefly, landcover per a high resolution landcover dataset (University of Vermont Spatial Analysis Laboratory 2016) was examined within 100 feet of USGS High-Resolution NHD flowlines. To determine riparian buffering within the "agricultural area," a polygon tool was used to clip riparian areas that, based on cursory visible inspection, appeared to be in an agricultural-dominated valley or have significant, obvious agricultural land on at least one side. This was determined to be unnecessary for the UNT Penns Creek subwatershed, as the entire watershed was largely within an agricultural area. The selection polygon for the UNT Susquehanna River watershed is shown in Figure 14. Then the sum of raster pixels that were classified as either "Emergent Wetlands", "Tree Canopy" or "Shrub/Scrub" was divided by the total number of non-water pixels to determine percent riparian buffer. Using this methodology, percent riparian buffer was determined to be 40% in the agricultural area of the impaired watershed versus 57% in the reference watershed.

An additional reduction credit was given to the reference watershed to account for its greater riparian buffering versus the impaired watershed. Applying a reduction credit solely to the reference watershed to account for its extra buffering was chosen as more appropriate than taking a reduction from both watersheds because the model has been calibrated at a number of actual sites (https://wikiwatershed.org/help/model-help/mmw-tech/) with varying amounts of existing riparian buffers. If a reduction were taken from all sites to account for existing buffers, the datapoints would likely have a poorer fit to the calibration curve versus simply providing an additional credit to a reference site.

When accounting for the buffering of croplands using the BMP Spreadsheet Tool (Version 2020-01-09, Evans et al. 2020) that was provided by MMW, the user enters the length of buffer on both sides of the stream. To estimate the extra length of buffers in the agricultural area of the reference watershed over the amount found in the impaired watershed, the length of USGS high-resolution NHD flowlines within the reference watershed was multiplied by the difference in the proportion of buffering between the agricultural area of the reference watershed versus that of the impaired watershed, and then by two since both sides of the stream are considered. The BMP spreadsheet tool then calculates sediment reduction using a similar methodology as the Chesapeake Assessment Scenario Tool (CAST). The length of riparian buffers is converted to acres, assuming that the buffers are 100 feet wide. For sediment loading, the spreadsheet tool assumes that 2 acres of croplands are treated per acre of buffer. Thus, twice the acreage of buffer is multiplied by the sediment loading rate calculated for croplands and then by a reduction coefficient of 0.54. The BMP spreadsheet tool is designed to account for the area of lost cropland and gained forest when riparian buffers are created. However, this part of the reduction equation was deleted for the present study since historic rather than proposed buffers were being accounted for.

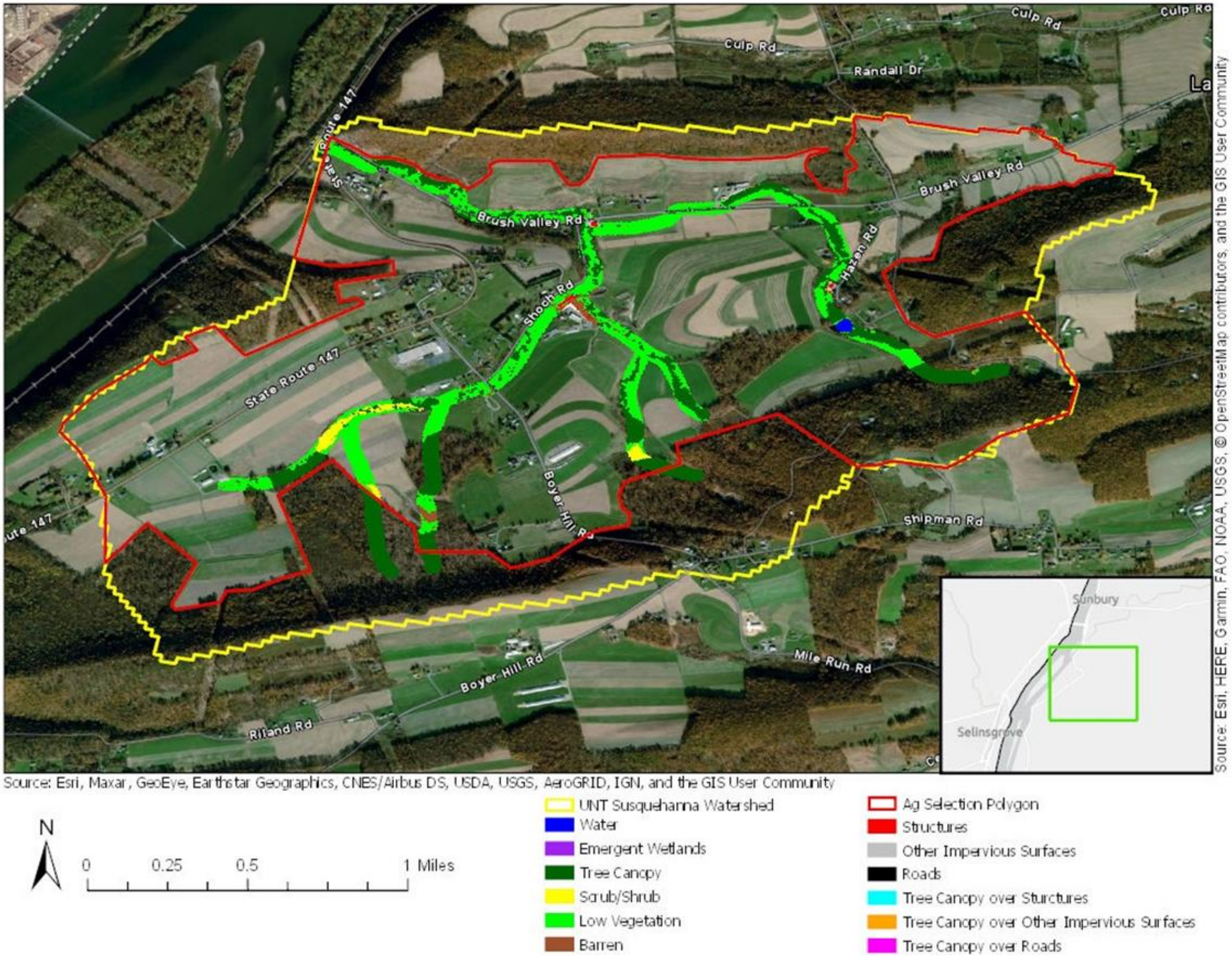

Figure 14. Analysis of riparian buffers in the UNT Susquehanna River watershed. It was estimated that the rate of riparian buffering in the agricultural area of this watershed was 40%.

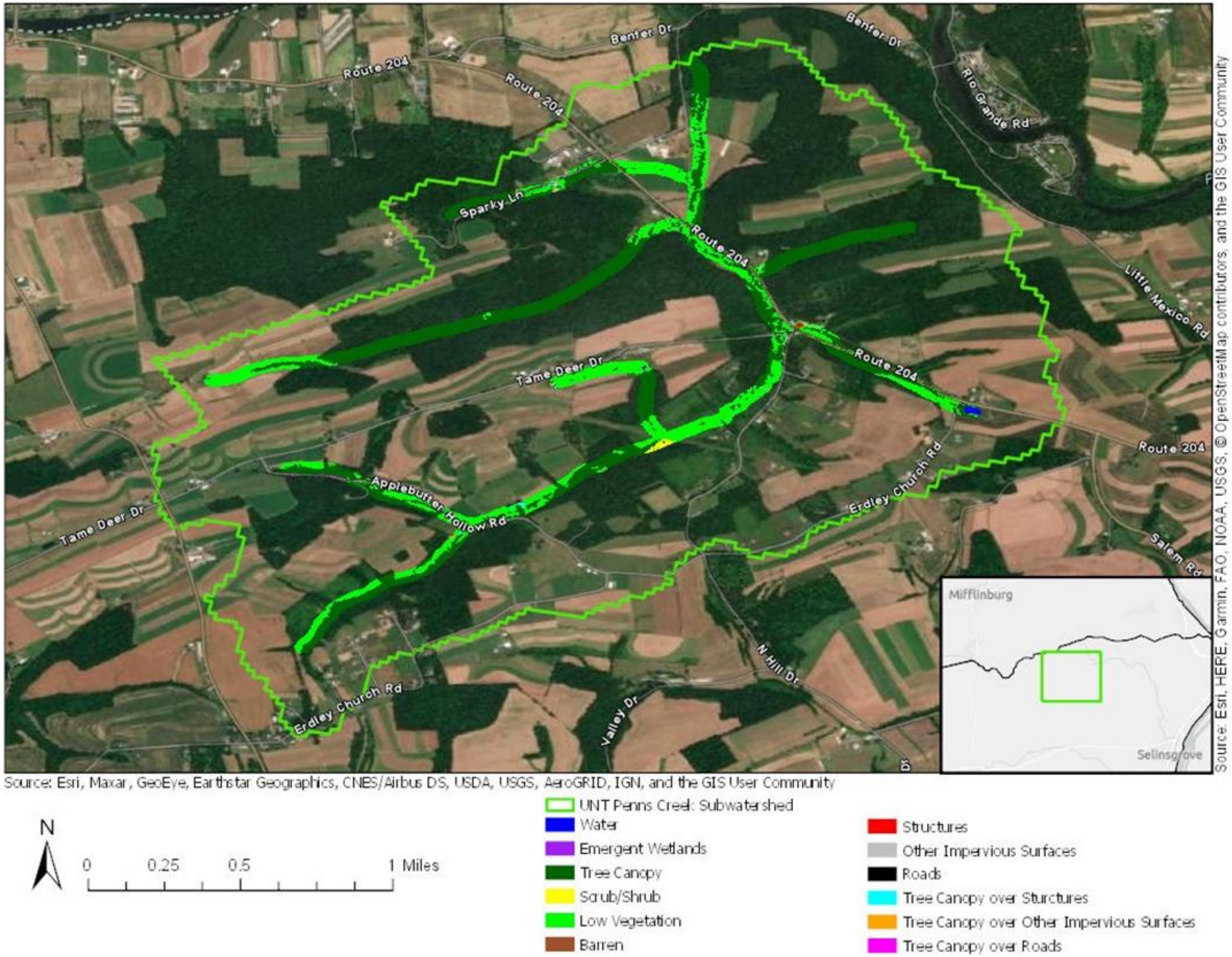

Figure 15. Analysis of riparian buffers in the UNT Penns Creek subwatershed. It was estimated that the rate of riparian buffering in this watershed was 57%.

CALCULATION OF THE $TMDL_{AVG}$

The mean annual sediment loading rate for the unimpaired reference subwatershed (UNT Penns Creek) was estimated to be 796 pounds per acre per year (Table 7). This was substantially lower than the estimated mean annual loading rate in the impaired UNT Susquehanna River watershed (873 pounds per acre per year, Table 8). Thus, to achieve the loading rate of the unimpaired watershed, sediment loading in the UNT Susquehanna River watershed should be reduced to 1,446,929 pounds per year or less (Table 9).

Table 7. Existing annual average loading values for the UNT Penns Creek subwatershed, reference.

Source	**Area** ac	**Sediment** (lbs/yr)	**Unit Area Load** (lbs/ac*yr)
Hay/Pasture	235	54,209	231
Cropland	711	1,389,769	1,954
Forest and Shrub/Scrub	738	2,422	3
Wetland	0	4	
Grassland/Herbaceous	5	299	61
Low Density Mixed Development	138	1,554	11
Medium Density Mixed Development	7	553	75
High Density Mixed	0	37	
Streambank[1]		67,682	
Point Sources		0	
Riparian Buffer Discount[2]		-55,838	
total	1,835	1,460,690	796

[1]"Streambank" sediment loads were calculated using Model My Watershed's streambank routine which uses length rather than area.
[2]Riparian buffer discount takes into account sediment reduction attributed to the extra buffering in the reference watershed.

Table 8. Existing annual average loading values for the UNT Susquehanna River watershed, impaired.

Source	**Area** ac	**Sediment** lbs/yr	**Unit Area Load,** lb/(ac*yr)
Hay/Pasture	254	358,488	1,410
Cropland	686	1,160,049	1,690
Forest and Shrub/Scrub	699	3,431	5
Wetland	0	1	

Grassland/Herbaceous	2	112	45
Low Intensity Mixed Development	158	1,795	11
Medium Intensity Mixed Development	12	830	67
High Intensity Mixed Development	5	317	64
Streambank[1]		61,037	
Point Sources		0	
total	1,817	1,586,060	873

Table 9. Calculation of an annual average TMDL value for the UNT Susquehanna River watershed.

Pollutant	**Reference Mean Loading Rate** lbs/(ac*yr)	**Impaired Watershed Area** ac	**Target TMDL$_{Avg}$** lbs/yr
Sediment	796	1,817	1,446,929

CALCULATION OF LOAD ALLOCATIONS

In the TMDL equation, the load allocation (LA) is the load derived from nonpoint sources. The LA is further divided into the adjusted loads allocation (ALA), which is comprised of the nonpoint sources causing the impairment and targeted for reduction, as well as the loads not reduced (LNR), which is comprised of the natural and anthropogenic sources that are not considered responsible for the impairment nor targeted for reduction. Thus:

LA = ALA + LNR

Considering that the TMDL is the sum of the margin of safety (MOS), the wasteload allocation (WLA), and the load allocation (LA):

TMDL = MOS + WLA + LA,

then the LA is calculated as follows:

LA = TMDL - MOS - WLA

Thus, before calculating the LA, the MOS and WLA must be defined.

Margin of Safety

The MOS is a portion of pollutant loading that is reserved to account for uncertainties. Reserving a portion of the load as a safety factor requires further load reductions from the ALA to achieve the TMDL. For this analysis, the MOS_{Avg} was explicitly designated as ten-percent of the $TMDL_{Avg}$ based on professional judgment. Thus:

$1,446,929$ lbs/yr $TMDL_{Avg}$ * 0.1 = 144,693 lbs/yr MOS_{Avg}

Wasteload Allocation

There were no existing NPDES permittees in the watershed in need of individual WLA (Table 4). Thus, the WLA will consist solely of a bulk reserve, which is a minor allowance for: existing dischargers not assigned individual WLAs as well as minor increases from point sources as a result of future growth of existing or new sources. The bulk reserve was assigned a value of 1% of the TMDL load.

Thus, the total WLA was calculated as:

1,446,929 lbs/yr $TMDL_{Avg}$ * 0.01 = 14,469 lbs/yr bulk $reserve_{Avg}$ + 0 lb/yr permitted loads = 14,469 lbs/yr WLA_{Avg}

Load Allocation

Now that the MOS and WLA have been defined, the LA is calculated as:

1,446,929 lbs/yr $TMDL_{Avg}$ – (144,693 lbs/yr MOS_{Avg} + 14,469 lbs/yr WLA_{Avg}) = 1,287,767 lbs/yr LA_{Avg}

Loads Not Reduced and Adjusted Load Allocation

Since the impairments addressed by this TMDL were for sedimentation due to agriculture, sediment contributions from forests, wetlands, open lands and developed lands within the UNT Susquehanna River watershed were considered loads not reduced (LNR). LNR_{Avg} was calculated to be 6,486 lbs/yr (Table 10).

The LNR is subtracted from the LA to determine the ALA:

1,287,767 lbs/yr LA_{Avg} – 6,486 lbs/yr LNR_{Avg} = 1,281,280 lbs/yr ALA_{Avg}

Table 10. Average annual load allocation, loads not reduced and adjusted load allocation

	Sediment, lbs/yr
Load Allocation (LA_{Avg})	**1,287,767**
Loads Not Reduced (LNR_{Avg}):	6,486
Forest	3,431
Wetland	1
Open Land (Grassland/Herbaceous)	112
Low Intensity Mixed Development	1,795
Medium Intensity Mixed Development	830
High Intensity Mixed Development	317
Adjusted Load Allocation (ALA_{Avg})	**1,281,280**

Note, the ALA is comprised of the anthropogenic sediment sources targeted for reduction: croplands, hay/pasture lands and streambanks (assuming an elevated erosion rate). The LNR is comprised of both natural and anthropogenic sediment sources. While anthropogenic, developed lands were considered minor sediment source in this watershed and thus not targeted for reduction. Forests, wetlands, and open lands were considered natural sediment sources.

CALCULATION OF SEDIMENT LOAD REDUCTIONS

To calculate load reductions by source, the ALA was further analyzed using the Equal Marginal Percent Reduction (EMPR) allocation method described in Appendix D. Although this UNT Susquehanna River sediment TMDL was developed to address impairments caused by agricultural activities, streambanks were also significant contributors to the sediment load in the watershed, and streambank erosion rates are influenced by agricultural activities. Thus, streambanks were included in the ALA and targeted for reduction. In this evaluation, all source sectors were given the same reduction goal of 19% (Table 11).

Table 11. Average annual sediment load allocations for source sectors in the UNT Susquehanna River watershed.

Source Sector	Acres	Load Allocation lbs/yr	Current Load lbs/yr	Reduction Goal
CROPLAND	686	940,981	1,160,049	19%
HAY/PASTURE	254	290,790	358,488	19%
STREAMBANK		49,510	61,037	19%
AGGREGATE		1,281,280	1,579,574	19%

CALCULATION OF A DAILY MAXIMUM "$TMDL_{MAX}$" VALUE

When choosing the best timescale for expressing pollutant loading limits for siltation, two major factors must be considered:

1) Sediment loading is driven by storm events, and loads vary greatly even under natural conditions.
2) Siltation pollution typically harms aquatic communities through habitat degradation as a result of chronically excessive loading.

Considering then that siltation pollution has more to do with chronic degradation rather than acutely toxic loads/concentrations, pollution reduction goals based on average annual conditions are much more relevant than daily maximum values. Nevertheless, a truer "Total Maximum Daily Load" ($TMDL_{Max}$) is also calculated in the following.

MMW currently does not report daily loading rates, but its predecessor program, "MapShed" does. Note, that the original versions of the modelling program reported loads as monthly, yearly, or mean annual, and the ability to report daily output was added in 2013. Rather than reconstruct the modelling routines, it was decided to back-calculate these values using monthly loads and daily hydrology results. For sediment, monthly upland loads were reallocated to days proportionally based on the amount of monthly runoff that each day accounted for. Streambanks were handled similarly, except that stream flow rather than runoff was used. In cases where point sources are considered by the model, the monthly loads are simply divided by the number of days in the month. Additional methods relevant to nutrient loading were also developed, but they are beyond the context of the present study. (Dr. Barry Evans, MMW Developer, personal communication).

Thus, for the calculation of a $TMDL_{Max}$ value, modelling was initially conducted in MMW as described above, and the “Export GMS” feature was used to provide an input data file that was run in the Generalized Watershed Loading Functions-Enhanced Version 1.51 Model Simulation application provided with MapShed. The daily output was opened in Microsoft Excel, and current “maximum” daily loads were calculated as the 99^{th} percentiles (using the percentile.exc function) of estimated daily sediment loads in both the UNT Susquehanna River (impaired) and UNT Penns Creek (reference) watersheds. The first year of data was excluded to account for the time it takes for the model calculations to become reliable. The 99^{th} percentile was chosen because 1) sediment loading increases with the size of storm events, so, as long as there could be an even larger flood, a true upper limit to sediment loading cannot be defined and 2) 99% of the time achievement of water quality criteria is prescribed for other types of pollutants at 25 Pa. Code *§* 96.3(e).

As with the average loading values reported previously (see the Hydrologic / Water Quality Modelling section), a correction was made for the additional amount of existing riparian buffers in the reference watershed versus the impaired watershed. This was calculated simply by reducing the 99^{th} percentile loading rate for the reference subwatershed by the same reduction proportion calculated previously for the average loading rate. After this, any relevant daily maximum point source loads, based eDMR data if available, were added to the watershed totals (note that this was unnecessary in the present study, see Tables 4 and 6).

Then, similarly to the $TMDL_{Avg}$ value reported in Table 9, $TMDL_{Max}$ was calculated as the 99^{th} percentile daily load of the reference subwatershed divided by the acres of the reference subwatershed and then multiplied by the acres of the impaired watershed. Thus, the $TMDL_{Max}$ loading rate was calculated as 60,818 pounds per day (Table 12), which would be a 12% reduction from the UNT Susquehanna River watershed’s current 99^{th} percentile daily loading rate of 69,214 pounds per day.

Table 12. Calculation of $TMDL_{Max}$ for the UNT Susquehanna River watershed.

Pollutant	**Reference 99^{th} Percentile Loading Rate** lbs/(ac*d)	**Impaired Watershed Total Land Area** ac	**Target $TMDL_{Max}$** lbs/d
Sediment	33.5	1,835	60,818

Also, in accordance with the previous “Calculation of Load Allocations” section, the WLA_{Max} will consist solely of a bulk reserve, which was defined as 1% of the $TMDL_{Max}$. The MOS_{Max} was defined as 10% of the $TMDL_{Max}$. The LA_{Max} was then calculated as the amount remaining after subtracting the WLA_{Max} and the MOS_{Max} from the $TMDL_{Max}$. See Table 13 for a summary of these $TMDL_{Max}$ variables.

Table 13. 99th percentile of daily loading TMDL ($TMDL_{Max}$) variables for the UNT Susquehanna River watershed. All values are lbs/d.

Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}
Sediment	60,818	6,082	608	54,128

Mapshed did not break down daily loads by land cover type. Thus, the daily maximum load allocation variables were calculated assuming the same distribution as occurred for the annual average load allocation variables. For instance, if the streambanks allocation was 4% of LA_{Avg} it was assumed that it was also 4% of LA_{Max}. While the distribution of sources likely changes with varying flow levels, this might be an acceptable assumption considering that the largest flow events may control the bulk of annual sediment loading (Sloto et al. 2012). See Table 14 for a summary of the LA_{Max} variables.

Table 14. Allocation of the 99th percentile daily load allocation (LA_{Max}) for the UNT Susquehanna River watershed.

	Annual Average (lbs/yr)	**Proportion of Load Allocation**[1]	**Max Daily** (lbs/d)
Load Allocation	1,287,767		54,128
Loads Not Reduced	6,486	0.005	273
Adjusted Loads Allocation	1,281,280	0.995	53,856
Croplands	940,981	0.73	39,552
Hay/Pasturelands	290,790	0.23	12,223
Streambanks	49,510	0.04	2,081

[1]Because the modelling program did not break down daily loadings by land cover types, the load allocations for $TMDL_{Max}$ were calculated by assuming the same distribution as occurred for the LA_{Avg} variables. For instance, if the streambanks allocation was 4% of LA_{Avg} it was assumed that it was also 4% of LA_{Max}.

Because sediment loading varies so greatly with discharge, the $TMDL_{Max}$ value would probably only be relevant on a handful of days each year with the highest flow conditions. And, while these times are especially important to overall annual sediment loading (Sloto and Olson 2011, Sloto et al. 2012), it is cautioned that reliance solely on a $TMDL_{Max}$ value may not be protective of the UNT Susquehanna River watershed since chronic excessive sediment inputs occurring at lower discharge levels may be ignored. Take for instance an extreme scenario where the $TMDL_{Max}$ was met every day but never exceeded. In this case, the annual sediment loading in the UNT Susquehanna River watershed would skyrocket to 22,198,740 lbs/yr, which is approximately fourteen-times the current annual average. The $TMDL_{Avg}$ value on the other hand is sensitive to typical conditions, extreme events, and long-term effects, and thus is the most relevant of the two TMDL targets for achieving restoration in the UNT Susquehanna River watershed. Therefore, BMP implementation would ultimately be deemed adequate if the prescribed annual average reduction was satisfied.

CONSIDERATION OF CRITICAL CONDITIONS AND SEASONAL VARIATIONS

According to MMW's technical documentation (Stroud Water Research Center 2023), MMW uses a "continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads based on the daily water balance accumulated to monthly values." The source of the weather data (precipitation and temperature) was a dataset compiled by USEPA ranging from 1961-1990. Therefore, variable flow conditions and seasonal changes are inherently accounted for in the loading calculations. Furthermore, this document calculates both annual average and 99th percentile daily TMDL values. See the discussion of the relevance of these values in the previous section. Seeking to support both of these values will be protective under both long-term average and extreme flow event conditions.

RECOMMENDATIONS

This document proposes a 9% reduction in annual average sediment loading for the UNT Susquehanna River watershed. To achieve this goal while maintaining a margin of safety and minor allowance for point sources, annual average sediment loading from croplands, hay/pasture lands and streambanks should each be reduced by 19%. The 99th percentile daily sediment loading should be reduced by 12%. Reductions in stream sediment loading due to agricultural activities can be made through the implementation of required Erosion and Sediment Control Plans (Pennsylvania Clean Streams Law, Title 25 Environmental Protection, § 102.4, see also Appendix E) and through the use of BMPs such as conservation tillage, cover crops, vegetated filter strips, rotational grazing, livestock exclusion fencing, riparian buffers, etc.

It should be noted that there has been much recent progress in BMP implementation in the UNT Susquehanna River watershed (Figure 8). Based on coordination with DEP staff, the Northumberland County Conservation District, and a review of BMP data in the Practice Keeper database, it is estimated that recent BMP implementation may have already reduced sediment loading within the watershed by approximately 100,000 lbs/yr. If so, this would be about a third of the way towards the overall sediment load reduction prescribed for the watershed (Table 11). It should be cautioned however, that these reductions are based on preliminary analyses, and details about these BMPs and their crediting are not provided herein in order to protect landowner privacy. This being the case, recent BMP implementation was not credited when reporting the UNT Susquehanna River's current loading above (Table 8). But, such recent work could be credited if a watershed restoration plan is developed as a follow-up to this TMDL.

Development of a more detailed watershed implementation plan is recommended. Further exploration should be conducted to determine the most cost effective and environmentally protective combination of BMPs required for meeting the prescribed sediment reductions. According site observations, additional streambank stabilization and livestock exclusion fencing would be especially beneficial for the tributary running along Shoch Road, and expansive forested riparian buffers should be installed in many areas throughout the watershed (Figure 14). Additional opportunities for BMPs such as greater use of conservation tillage and cover crops, grazing land management, drainageway buffers, and the retirement of marginal agricultural lands likely exist.

Use of forested riparian buffers is widely recognized as one of the best ways to promote stream health. Riparian buffers protect streams from sedimentation and nutrient impairments by filtering these pollutants from runoff and floodwaters and by protecting streambanks from erosion.

Furthermore, riparian buffers are also beneficial for many other reasons beyond just protecting from sedimentation and nutrients. For instance, riparian buffers may: filter out other pollutants such as pesticides; provide habitat and nutrition for aquatic, semi-aquatic and terrestrial organisms; and moderate stream temperature. Thus, use of forested riparian buffers should be encouraged wherever possible.

Key personnel from the regional DEP office, the County Conservation District, Susquehanna River Basin Commission (SRBC) and other state and local agencies and/or watershed groups should be involved in developing a restoration strategy. There are a number of possible funding sources for agricultural BMPs and stream restoration projects, including: The Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act), PA DEP's Growing Greener Grant Program, United States Department of Agriculture's Natural Resource Conservation Service funding, and National Fish and Wildlife Foundation Grants.

PUBLIC PARTICIPATION

Public notice of a draft sediment TMDL for UNT Susquehanna River was published in the April 4, 2021 issue of the *Pennsylvania Bulletin* to foster public comment. A 30-day period was provided for the submittal of comments. Public comments and their responses were placed in Appendix F. Due to subsequent updates, an additional 30-day public comment period will commence upon publication of a notice in the June 10, 2023 issue of the *Pennsylvania Bulletin.* Additional public comments and their responses will be placed in Appendix F.

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APPENDIX A: BACKGROUND ON STREAM ASSESSMENT METHODOLOGY

Note that the following contains generalizations about DEP's most commonly used aquatic life assessment methods, but doesn't seek to describe all of the current and historic variations of such methodology. For more information, see DEP's *Assessment Methodology for Streams and Rivers* (Shull and Whiteash 2021).
Documentation of other historic methodologies is available upon request.

Prior to developing TMDLs for specific waterbodies, there must be sufficient data available to assess which streams are impaired and should be listed as such in the Integrated Water Quality Monitoring and Assessment Report. Prior to 2004, the impaired waters were found on the 303(d) List; from 2004 to present, the 303(d) List was incorporated into the Integrated Water Quality Monitoring and Assessment Report (IR) and found on List 5. Table A1. summarizes the changes to listing documents and assessment methods over time.

With guidance from USEPA, the states have developed methods for assessing the waters within their respective jurisdictions. From 1996-2006, the primary method adopted by DEP for evaluating waters found on the 303(d) lists (1998-2002) or in the IR (2004-2006) was the Statewide Surface Waters Assessment Protocol (SSWAP). SSWAP was a modification of the USEPA Rapid Bioassessment Protocol II (RPB-II) and provided a more consistent approach to assessing Pennsylvania's streams.

The assessment method called for selecting representative stream segments based on factors such as surrounding landuses, stream characteristics, surface geology, and point source discharge locations. The biologist was to select as many sites as necessary to establish an accurate assessment for a stream segment; the length of the stream segment could vary between sites. The biological surveys were to include kick-screen sampling of benthic macroinvertebrates, habitat surveys, and measurements of pH, temperature, conductivity, dissolved oxygen, and alkalinity. Benthic macroinvertebrates were typically identified to the family level in the field.

The listings found in the Integrated Water Quality Monitoring and Assessment Reports from 2008 to 2018 were derived based on the Instream Comprehensive Evaluation protocol (ICE). Like the superseded SSWAP protocol, the ICE protocol called for selecting representative segments based on factors such as surrounding landuses, stream characteristics, surface geology, and point source discharge locations. The biologist was to select as many sites as necessary to establish an accurate assessment for a stream segment; the length of the stream segment could vary between sites. The biological surveys were to include D-frame kicknet sampling of benthic macroinvertebrates, habitat surveys, and measurements of pH, temperature, conductivity, dissolved oxygen, and alkalinity. Collected samples were returned to the laboratory where the samples were typically to be subsampled for a target benthic macroinvertebrate sample of 200 ± 20% (N = 160-240). The benthic macroinvertebrates in this subsample were typically identified to the generic level. The ICE protocol is a modification of the USEPA Rapid Bioassessment Protocol III (RPB-III) and provides a more rigorous and consistent approach to assessing Pennsylvania's streams than the SSWAP. More recent listings from 2020 to present were based on updated data collection protocols and Aquatic Life Use (ALU) assessment methods that are specific to the use(s) being assessed.

After these surveys (SSWAP, 1998-2006 lists; or ICE, 2008-2018 lists; ALU 2020-present lists) are completed, biologists are to determine the status of the stream segment. Decisions are to be based on the performance of the segment using a series of biological metrics. If the stream segment is classified as impaired, it is to be listed on the state's 303(d) List, or presently, the IR with the source and cause documented.

Once a stream segment is listed as impaired, a TMDL typically must be developed for it. A TMDL addresses only one pollutant. If a stream segment is impaired by multiple pollutants, each pollutant generally receives a separate and specific TMDL within that stream segment. Adjoining stream segments with the same source and cause listings may be addressed collectively on a watershed basis.

Table A1. Impairment Documentation and Assessment Chronology

Listing Date:	Listing Document:	Assessment Method:
1998	303(d) List	SSWAP
2002	303(d) List	SSWAP
2004	Integrated List	SSWAP
2006	Integrated List	SSWAP
2008-2018	Integrated List	ICE
2020-present	Integrated List	ALU

APPENDIX B: MODEL MY WATERSHED GENERATED DATA TABLES

Table B1. Model My Watershed land cover outputs for the UNT Susquehanna River watershed based on NLCD 2019.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.01	0.16
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	0.45	6.09
Developed, Low Intensity	22	0.19	2.55
Developed, Medium Intensity	23	0.05	0.74
Developed, High Intensity	24	0.02	0.28
Barren Land (Rock/Sand/Clay)	31	0	0
Deciduous Forest	41	2.69	36.49
Evergreen Forest	42	0	0
Mixed Forest	43	0.14	1.96
Shrub/Scrub	52	0	0
Grassland/Herbaceous	71	0.01	0.1
Pasture/Hay	81	1.03	13.93
Cultivated Crops	82	2.78	37.66
Woody Wetlands	90	0	0
Emergent Herbaceous Wetlands	95	0	0.04
Total		7.38	100

Table B2. Model My Watershed land cover outputs for the UNT Penns Creek subwatershed based on NLCD 2019.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0	0
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	0.41	5.45
Developed, Low Intensity	22	0.15	2.05
Developed, Medium Intensity	23	0.03	0.4
Developed, High Intensity	24	0	0.02
Barren Land (Rock/Sand/Clay)	31	0	0
Deciduous Forest	41	2.17	29.24
Evergreen Forest	42	0.01	0.12
Mixed Forest	43	0.8	10.73
Shrub/Scrub	52	0.01	0.17
Grassland/Herbaceous	71	0.02	0.21
Pasture/Hay	81	0.95	12.75
Cultivated Crops	82	2.88	38.8
Woody Wetlands	90	0	0.06
Emergent Herbaceous Wetlands	95	0	0
Total		7.43	100

Table B3. Model My Watershed hydrology outputs for the UNT Susquehanna River watershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.73	0.99	4.75	0	0.29	7.15
Feb	6.42	1.22	5.2	0	0.45	7.31
Mar	7.39	0.62	6.78	0	1.61	8.36
Apr	6.29	0.17	6.12	0	4.26	8.41
May	4.48	0.14	4.34	0	8.44	10.51
Jun	3.57	0.94	2.64	0	11.96	10.58
Jul	1.37	0.19	1.18	0	11.74	9.86
Aug	0.48	0.14	0.34	0	9.29	8.64
Sep	0.95	0.82	0.13	0	6.06	9.04
Oct	1.23	0.63	0.6	0	3.44	8.06
Nov	2.34	0.49	1.85	0	1.62	9.38
Dec	5.09	0.71	4.38	0	0.63	8.11
Total	45.34	7.06	38.31	0	59.79	105.41

Table B4. Model My Watershed hydrology outputs for the UNT Penns Creek subwatershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.98	0.93	5.05	0	0.28	7.15
Feb	6.51	1.15	5.36	0	0.44	7.31
Mar	7.48	0.57	6.91	0	1.58	8.36
Apr	6.33	0.15	6.17	0	4.23	8.41
May	4.45	0.13	4.32	0	8.4	10.51
Jun	3.52	0.92	2.6	0	11.63	10.58
Jul	1.31	0.18	1.14	0	11.17	9.86
Aug	0.44	0.13	0.32	0	9.01	8.64
Sep	0.97	0.79	0.18	0	5.86	9.04
Oct	1.5	0.6	0.9	0	3.42	8.06
Nov	2.81	0.45	2.36	0	1.6	9.38
Dec	5.65	0.67	4.98	0	0.62	8.11
Total	46.95	6.67	40.29	0	58.24	105.41

Table B5. Model My Watershed outputs for sediment in the UNT Susquehanna River watershed.

Sources	Sediment (kg)
Hay/Pasture	162,579.60
Cropland	526,099.50
Wooded Areas	1,556.00
Wetlands	0.5
Open Land	50.6
Barren Areas	0
Low-Density Mixed	240.4
Medium-Density Mixed	376.6
High-Density Mixed	143.8
Low-Density Open Space	573.7
Farm Animals	0
Stream Bank Erosion	27,681.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B6. Model My Watershed outputs for sediment in the UNT Penns Creek subwatershed.

Sources	Sediment (kg)
Hay/Pasture	24,584.40
Cropland	630,280.70
Wooded Areas	1,098.50
Wetlands	1.7
Open Land	135.5
Barren Areas	0
Low-Density Mixed	192.5
Medium-Density Mixed	250.7
High-Density Mixed	16.7
Low-Density Open Space	512.2
Farm Animals	0
Stream Bank Erosion	30,695.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

APPENDIX C: STREAM SEGMENTS IN THE UNT SUSQUEHANNA WATERSHED WITH AQUATIC LIFE USE IMPAIRMENTS

Length (miles):	ATTAINS ID:	Impairment Source	Impairment Cause:	Date Listed As Impaired:
0.01	PA-SCR-54962623	AGRICULTURE	SILTATION	2002
0.78	PA-SCR-54962765	AGRICULTURE	SILTATION	2002
1.01	PA-SCR-54962959	AGRICULTURE	SILTATION	2002
0.05	PA-SCR-54962995	AGRICULTURE	SILTATION	2002
0.22	PA-SCR-54963001	AGRICULTURE	SILTATION	2002
0.40	PA-SCR-54963089	AGRICULTURE	SILTATION	2002
0.24	PA-SCR-54963119	AGRICULTURE	SILTATION	2002
0.26	PA-SCR-54963277	AGRICULTURE	SILTATION	2002
0.51	PA-SCR-54963345	AGRICULTURE	SILTATION	2002
0.21	PA-SCR-54963409	AGRICULTURE	SILTATION	2002
0.01	PA-SCR-54962623	AGRICULTURE	ORGANIC ENRICHMENT	2002
0.78	PA-SCR-54962765	AGRICULTURE	ORGANIC ENRICHMENT	2002
1.01	PA-SCR-54962959	AGRICULTURE	ORGANIC ENRICHMENT	2002
0.05	PA-SCR-54962995	AGRICULTURE	ORGANIC ENRICHMENT	2002
0.22	PA-SCR-54963001	AGRICULTURE	ORGANIC ENRICHMENT	2002
0.40	PA-SCR-54963089	AGRICULTURE	ORGANIC ENRICHMENT	2002
0.24	PA-SCR-54963119	AGRICULTURE	ORGANIC ENRICHMENT	2002
0.26	PA-SCR-54963277	AGRICULTURE	ORGANIC ENRICHMENT	2002
0.51	PA-SCR-54963345	AGRICULTURE	ORGANIC ENRICHMENT	2002
0.21	PA-SCR-54963409	AGRICULTURE	ORGANIC ENRICHMENT	2002

Note that this TMDL only addresses the above siltation impairments.

APPENDIX D: EQUAL MARGINAL PERCENT REDUCTION METHOD

The Equal Marginal Percent Reduction (EMPR) allocation method was used to distribute the Adjusted Load Allocation (ALA) between the appropriate contributing nonpoint sources. The load allocation and EMPR procedures were performed using a MS Excel spreadsheet. The 5 major steps identified in the spreadsheet are summarized below:

Step 1: Calculation of the TMDL based on impaired watershed size and unit area loading rate of reference watershed.

Step 2: Calculation of Adjusted Load Allocation based on TMDL, MOS, WLA and existing loads not reduced.

Step 3: Actual EMPR Process:

a. Each landuse/source load is compared with the total ALA to determine if any contributor would exceed the ALA by itself. The evaluation is carried out as if each source is the only contributor to the pollutant load of the receiving waterbody. If the contributor exceeds the ALA, that contributor would be reduced to the ALA. If a contributor is less than the ALA, it is set at the existing load. This is the baseline portion of EMPR.

b. After any necessary reductions have been made in the baseline, the multiple analyses are run. The multiple analyses will sum all the baseline loads and compare them to the ALA. If the ALA is exceeded, an equal percent reduction will be made to all contributors' baseline values. After any necessary reductions in the multiple analyses, the final reduction percentage for each contributor can be computed.

Step 4: Calculation of total loading rate of all sources receiving reductions.

Step 5: Summary of existing loads, final load allocations, and percent reduction for each pollutant source

Table D1. Equal marginal percent reduction calculations for the UNT Susquehanna River watershed.

	Current Load, lbs/yr	Any > ALA?	If > ALA, reduce to ALA	How much does sum exceed ALA?	Proportions of total after initial adjust	Assign reductions still needed per proportions after intial adjust	ALA: subtract reductions still needed from initial adjust	proportion Reduction
Cropland	1,160,049	no	1,160,049		0.73	219,069	940,981	0.19
Hay/Pasture	358,488	no	358,488	298,294	0.23	67,698	290,790	0.19
Streambank	61,037	no	61,037		0.04	11,526	49,510	0.19
sum	**1,579,574**		**1,579,574**		**1.00**	**298,294**	**1,281,280**	**0.19**

APPENDIX E: LEGAL BASIS FOR THE TMDL AND WATER QUALITY REGULATIONS FOR AGRICULTURAL OPERATIONS

CLEAN WATER ACT REQUIREMENTS

Section 303(d) of the 1972 Clean Water Act requires states, territories, and authorized tribes to establish water quality standards. The water quality standards identify the uses for each waterbody and the scientific criteria needed to support that use. Uses can include designations for drinking water supply, contact recreation (swimming), and aquatic life support. Minimum goals set by the Clean Water Act require that all waters be “fishable” and “swimmable.”
Additionally, the federal Clean Water Act and USEPA’s implementing regulations (40 CFR 130) require:

- States to develop lists of impaired waters for which current pollution controls are not stringent enough to meet water quality standards (the list is used to determine which streams need TMDLs);
- States to establish priority rankings for waters on the lists based on severity of pollution and the designated use of the waterbody; states must also identify those waters for which TMDLs will be developed and a schedule for development;
- States to submit the list of waters to USEPA every two years (April 1 of the even numbered years);
- States to develop TMDLs, specifying a pollutant budget that meets state water quality standards and allocate pollutant loads among pollution sources in a watershed, e.g., point and nonpoint sources; and
- USEPA to approve or disapprove state lists and TMDLs within 30 days of final submission.

PENNSYLVANIA CLEAN STREAMS LAW REQUIREMENTS, AGRICULTURAL OPERATIONS

Pennsylvania farms are required by law to operate within regulatory compliance by implementing the applicable requirements outlined in the Pennsylvania Clean Streams Law, Title 25 Environmental Protection, Part I DEP, Subpart C Protection of Natural Resources, Article II Water Resources, Chapters: § 91.36 Pollution control and prevention at agricultural operations, § 92a.29 CAFO and § 102.4 Erosion and sediment control requirements. Water quality regulations can be found at following website: http://www.pacode.com/secure/data/025/025toc.html

Agricultural regulations are designed to reduce the amount of sediment and nutrients reaching the streams and groundwater in a watershed.

APPENDIX F: COMMENT AND RESPONSE

NORTHUMBERLAND COUNTY
Conservation District

441 Plum Creek Road
Sunbury, PA 17801

May 21, 2021

PA Department of Environmental Protection (DEP)
Attn: Michael R. Morris, Water Program Specialist
Bureau of Clean Water
PO Box 8774
Harrisburg, PA 17105-8774
Transmitted via email: michamorri@pa.gov

RE: Request for Comment -
Proposed Total Maximum Daily Logs (TMDLs) for the UNT Susquehanna River Watershed in Northumberland County (Brush Valley Creek)
Pennsylvania Bulletin, Volume 51, Number 17, Page 2355

Dear Mr. Morris:

On behalf of the Northumberland County Conservation District, I am submitting the below comments regarding the proposed TMDL for the UNT Susquehanna River Watershed (Brush Valley Creek) in Northumberland County.

1) Under "TMDL Approach", page 5, we request the following step be added to the agency's approach: "contact relevant groups within the mentioned watershed that may have more information about current BMP implementation."

    a) This step would allow for conservation districts, watershed groups, and other relevant, organized groups to have input, and it would ensure the most up-to-date information is used before the creation of the TMDL, and before it goes out for public comment.

2) Under "Selection of a Reference Watershed"

    a) On pages 6-7, Table 5:

        i) Soil infiltration groups are not defined in the table. If someone does not know how to access this data via ModelMyWatershed, they would not know what these soil groups mean.

    b) When looking at the Surface Runoff (in/yr) we found the UNT-Susquehanna (Brush Valley) had a total surface runoff of 2.3 in/yr, and the UNT-Penns had a total surface runoff of 2.12 in/yr.

i) In the TMDL, they are both listed as a 2.4 for Average Surface Runoff, in/yr, but on ModelMyWatershed, these numbers are totals, not averages.

c) The "Average Precipitation" should be "Total Precipitation."

d) The "Stream Channel Slope" should be "Average Stream Channel Slope."

3) Additionally, the soil infiltration rates are not as comparable as the TMDL may suggest.

a) For the UNT-Susquehanna (Brush Valley) watershed, the infiltration rate would be slower compared to the reference watershed, UNT-Penns. This is because there are greater amounts of soil group D (very slow infiltration), and less of soil group A (high infiltration) in the UNT-Susquehanna (Brush Valley) watershed when compared to the reference watershed, UNT-Penns.

b) While the land use may look very similar between the UNT-Susquehanna (Brush Valley) and UNT-Penns, the soil landscapes and hydrology are different.

c) When referencing the soil maps on ModelMyWatershed and looking at Figures 1, 3, 14, and 15, you can see that the slower-infiltrating soils of UNT-Susquehanna are mostly forested.

i) Forests tend to help increase infiltration of water into soils. However, if the forests are in soils that have poor infiltration due to soil types, it is reasonable to assume the forests may not be infiltrating as much as forests in well-infiltrating soils.

(1) There is a difference in location of these soil types. The very slow-infiltrating soil in the UNT-Susquehanna (Brush Valley) is located near the headwaters of the UNT-Susquehanna (Brush Valley). The very-slow-infiltrating soils of the UNT-Penns watershed are not located near the headwaters. The headwaters of the UNT-Susquehanna (Brush Valley) are in areas with greater slope than the rest of the watershed.

d) Slow infiltration rates can cause surface runoff and erosion in sloping areas.

i) The UNT-Susquehanna drainage basin (Brush Valley) has a 1% greater average slope than the reference watershed (UNT-Penns).

4) Therefore, the reference watershed (UNT-Penns) has greater infiltration and less slope than the UNT-Susquehanna (Brush Valley) watershed.

a) It would be reasonable to assume that the UNT-Susquehanna (Brush Valley) will naturally have more erosion and sedimentation than the reference watershed (UNT-Penns) due to slower-infiltrating soils and greater slope.

5) Under "Hydrologic/Water Quality Modeling" page 26, Figure 14.

   a) The map shows that a section of forested land cover is included in the "Ag selection polygon." The forested area included in the Ag selection polygon is directly north of the label for Shipman Road.

Main points:

- The reference watershed (UNT-Penns) looks very similar to the UNT-Susquehanna (Brush Valley) watershed from a land-use perspective, but from a hydrologic perspective (soil infiltration and surface runoff), it may be less similar. This could make it more difficult for water quality standards to be reached, even if the recommended BMPs are implemented because there is naturally more surface runoff in the UNT-Susquehanna (Brush Valley) watershed when compared to the UNT-Penns (reference) watershed.

- Please consider adding a step to the "TMDL Approach" section that includes contacting relevant, organized groups within the mentioned watershed that may have more information about current BMP implementation.

If clarification is needed on any of the above comments, please contact me at 570-495-4665 x305 or jbecker@nccdpa.org.

Thank you for the opportunity to provide public comment(s) on the proposed TMDL.

Best,

Judy Becker

Judy Becker
District Manager
Northumberland County Conservation District

DEP Responses to Northumberland County Conservation District's Letter

In the following, number and letter labels correspond to those used in the above letter.

1. Per 25 Pa. Code § 96.7(b), publication of a notice in the *Pennsylvania Bulletin* and providing a minimum 30-day comment period is the prescribed mechanism for Public Participation. The document is still draft when the notice goes out, and where appropriate, DEP incorporates relevant information collected during the comment period into the final draft prior to submission to EPA for approval. It is believed that putting the draft out is a more productive way of gaining pertinent comments versus asking for information at the onset of the study with no draft and little context provided.

   In response to the comments provided on the present TMDL, DEP made updates and delayed finalization of the TMDL so that the Northumberland County Conservation District (NCCD) could provide additional BMP information. DEP then provided the updated draft to the NCCD for additional review and comment. Given their wish to be involved in the process up front, the author of this TMDL informed the NCCD of another TMDL proposed for development in their county. The author plans to continue to provide such advance notice to the NCCD for future TMDLs.

2. a) i). This information has been added as a footnote to Table 5.
   b). The commenter may have gotten different values if they used what was reported by default in MMW, which was based on NLCD 2011. However, as was explained in the "Hydrologic / Water Quality Modelling" section, land cover was updated to reflect USDA's 2020 Cropland Data Layer, and this changes surface runoff rates. Modelling has now been updated with a newer version of Model My Watershed that uses NLCD 2019.

   b) i); c) Considering the units reported in the table (in/yr), the use of "average" is correct. The model first calculates average values for each month and then sums all 12 average months to get the average year. It would only make sense to say "total" if the units were inches per month. For more information, see the model's technical documentation.

   d) "Average" was added per the suggestion.

3. and 4. These comments correctly point out that the reference watershed is not exactly the same is the impaired watershed. In choosing a reference, more than twenty watersheds within the Susquehanna Lowland Section of the Ridge and Valley Physiographic Province were seriously considered. None of these references matched the impaired watershed exactly; if one did, they would likely share the same impairments. Thus, compromises are always made when using the reference watershed approach.

   The chosen reference was ultimately considered the best choice when balancing similarity to the impaired watershed while seeking a reasonable pollution reduction. Based on preliminary analysis, two other potential references appeared to match the impaired watershed more closely, including the distribution of soil drainage classes. However, their use would have resulted in far more drastic pollution reductions, which is inconsistent with finding the "total maximum daily load". Even though the chosen reference might not have been the most similar option, it still appears to be a good match for the impaired watershed. Plus, there is a 10% margin of safety factor to help account for uncertainties such as reference dissimilarity.

Finally, consider the potential implications of imperfect reference selection and what may be done to avoid negative consequences. Problems for NPDES permits are unlikely, since there were no such permits, and the bulk reserve would likely have sufficient capacity for future permittees. On the other hand, poor reference choice may have two ultimate effects for nonpoint source BMP implementation: 1) the prescribed pollution reduction may be too small, and thus BMPs that are estimated to achieve the target would fail to achieve water quality standards; or 2) the prescribed pollution reduction may be greater than needed to achieve water quality standards resulting in superfluous BMP implementation. To address these concerns, the following strategy could be used during restoration: implement progressively greater BMPs while making frequent assessments. If it is found that the stream is no longer impaired for siltation before the prescribed reductions are achieved, implementation could cease and development of a new more relaxed TMDL could be initiated. If however, impairments remained after the prescribed reductions are met, BMP implementation could continue and a new TMDL with a more stringent value could be requested.

5. Please refer to TMDL's the "Hydrologic / Water Quality Modeling" section where it says: "a polygon tool was used to clip riparian areas that, based on cursory visible inspection, appeared to be in an agricultural-dominated valley or have significant, obvious agricultural land on at least one side". Note the agricultural land within the watershed boundary north of Shipman Road, as well as just to the east of the upstream most point of the tributary in question.